Identifying migrants in Roman London using lead and strontium stable isotopes

Authors: Heidi Shaw*[1], Janet Montgomery[1], Rebecca Redfern[2], Rebecca Gowland[1], and Jane Evans[3]

[1]Department of Archaeology, Durham University, Dawson Building, South Road, Durham, DH1 3LE, UK
[2] Centre for Human Bioarchaeology, Museum of London, 150 London Wall, London, EC2Y 5HN UK
[3] NERC Isotope Geosciences Laboratory British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK
*Corresponding Author, PO Box 299, Anderson, California 96007, USA. HeidiAShaw@gmail.com

Abstract

The ancient settlement of *Londinium* (London) has long been characterized as a major commercial and bureaucratic centre of the Roman province of Britain (*Britannia*). Primary source information indicates that people were drawn to the city from around the Empire. Mortuary and archaeological material evidence also attest to its cosmopolitan nature and have long been used to characterize the people who are buried in *Londinium* and identify where they may have originated. Within the past decade, researchers have successfully applied isotopic analyses of strontium and oxygen to human remains from various settlements in Roman Britain in order to identify the migrant status of the inhabitants. Recent studies have highlighted the utility of lead isotopes for examining past mobility, particularly for the Roman period. The aim of this project, therefore, was to apply lead and strontium isotope analyses to dental enamel samples from twenty individuals excavated from *Londinium*. The results suggest that the geographic origins of the population of Roman London varied, comprising individuals local to *Londinium* and Britannia, but also from further afield in the Empire, including Rome. The findings from this study are a valuable addition to the growing stable isotope dataset that is helping to characterize the nature of migration in Roman Britain, and this has broader implications for interpreting the relationship of migration and identity in the province.

Keywords: Roman Britain, *Londinium*, mobility, ethnicity, funerary evidence

1.0 Introduction

The conquest of Britain (*Britannia)* by Rome in AD 43 initiated the integration of this small territory on the edge of the known Roman world into a vast Empire, whose dominions included much of Europe, the Middle East and North Africa (Mattingly, 2006). Primary sources and archaeological evidence reveal that because of military, enslavement, and other mercantile activities, many people lived and worked in multiple provinces during their lifetime (Adams and Laurence, 2001; George, 2013). In recent years, stable isotope analysis has been used to independently establish the presence of migrants and their likely place of origin (Montgomery, 2002; Molleson, et al., 1986; Leach et al., 2009; Chenery et al., 2010, 2011; Montgomery et al., 2010, 2011; Eckardt et al., 2009; Müldner et al., 2011). These analyses have added value to the epigraphic and archaeological evidence and enabled new perspectives on the construction of identity in the funerary record (Cool, 2010a; Eckardt, 2010, Eckardt, et al., 2014; Pearce, 2010).

In Britain, this integrated approach has reinvigorated Roman studies, with new results showing that migrants, whether free or enslaved, lived in urban and rural settlements from the earliest phases of the conquest. Such findings have informed our understanding and interpretation of post-conquest changes in burial practices, in addition to underlining the important role that migrants had in determining the nature and make-up of settlements and communities during this period (Cool, 2010a; Eckardt, et al., 2010, 2014; Pearce, 2010). London (*Londinium*) is ideally placed to investigate these changes, because it was founded in an area without an existing indigenous settlement, and established itself from the outset as a social and economic hub of the province (Marsden, 1986; Perring, 1991, 2015; Perring and Pitts, 2013). The limited epigraphic evidence from *Londinium* provides some insights into the geographical origins of its people, as this information was often included in people's funerary epitaphs. The epigraphic evidence suggests that *Londinium* was inhabited by people from France, Germany, the Mediterranean, and North Africa (Mattingly, 2011; Millett, 1996a, 1996b). To date, there have only been a limited number of small-scale isotope analysis studies for individuals recovered from *Londinium* to corroborate this (Montgomery et al, 2010; Millard, et al., 2013). This study represents the first to examine population mobility using strontium and lead stable isotopes from individuals buried in its cemeteries. Twenty individuals were selected, whose burial dates span the beginning and decline of *Londinium* (1^{st} to 5^{th} centuries AD) in order to investigate population origins, the extent to which an individual's origins were expressed in the funerary record, and how the correlation between a person's origins and funerary context might influence our understanding of their identity.

1.1 Roman London

There is no pre-Conquest evidence for an indigenous settlement in the location of the City and Greater London area. Rather, archaeological excavations have found evidence for the ritual use of the landscape and River Thames, and some isolated late Iron Age farmsteads (Marsden, 1986; Sidell, 2008). Recent discoveries have shown that the settlement of *Londinium* was established in c. AD 48 (Hill and Rowsome, 2011). The main settlement was situated on the north bank of the River Thames, with a suburb on the south bank that was linked by a river crossing at the lowest bridgeable point. Both of these areas were well placed for connecting land, river and sea traffic (Brigham, 1996) and the degree of organization and forethought in the early city planning demonstrates military involvement in the construction of *Londinium*. Archaeological and primary source evidence indicates that from the outset, the growing urban centre functioned primarily as a planned, but unofficial, centre of commerce and focus for goods traded from the surrounding region and Continent (Rowsome, 1996; Tomlin, 2006; Perring and Pitts, 2013; Wallace, 2014; Perring, 2015).

Londinium underwent an undulating pattern of growth and decline throughout Roman occupation. Archaeological evidence from the earliest phases (48-60 AD) highlights the mercantile nature of the settlement and the presence of migrant inhabitants, as evidenced by the many houses that had shop-fronts (Hill and Rowsome, 2011). Additionally, there is evidence for imported foods and material culture from Europe, particularly the southern and eastern Mediterranean (Hill and Rowsome, 2011). This evidence confirms the writings of Tacitus (Annals 14.33.1), who described the settlement as ‘a busy centre through its crowd of merchants and stores.’ However, much of *Londinium* was burnt and destroyed during the Boudican revolt of AD 60 (Marsden, 1986; Hill and Rowsome, 2011; Wallace, 2014).

After the rebellion, a programme of major public building work (i.e. a port) was begun and the settlement rebuilt. Archaeological evidence shows that the military were responsible for much of the construction work (Millett, 1996a, 1996b). By AD 100, the administrative centre of the province (*Britannia*) had shifted from the original capital at Colchester to *Londinium*, making it the base for Imperial and military activities (Marsden, 1986; Tomlin, 2006).

The third and fourth centuries are characterised by periods of decline, with abandonment of some areas, followed by evidence of brief episodes of revitalisation. These fluctuating fortunes mirror the wider political unrest in the Empire. During the later phase of Roman occupation, *Londinium* was given the honorary title of ‘*Augusta*’ and remained the financial hub and administrative centre of *Britannia* until AD 410. After this time, the population size appears to have decreased, as only the walled settlement on the north bank and the area on the southeast bank continued to be occupied, but there is evidence for its continued wealth in the form of luxury imports from the Continent (Marsden, 1986; Mattingly, 2006; Millett, 1996a, 1996b; Perring, 1991).

1.2 The people of Roman London

From its inception, *Londinium* was created and inhabited by people from across the Empire: military and civilian, enslaved and free, local and foreign. Epigraphic evidence from *Londinium* provides some insights into the geographical origins of its people. These refer to serving soldiers and army veterans, a sailor, merchants from Antioch (Turkey) (RIB 29) and Athens (Greece) (RIB 9) (see Holder, 2007). There is also evidence for connections to North Africa, with adult and child migrants identified by stable isotope analyses (Millard et al., 2013), funerary inscription evidence such as the partial inscription commemorating Tullia Numidia (RIB 23 cited in Wheeler, 1928, see also Holder, 2007), and a range of material culture depicting sub-Saharan people corresponds to notions of the ‘exotic’ in the Roman world (Eckardt, 2014, 79-81).

The importance of the settlement as a centre of commerce and administration is also documented in the inscription evidence. An incomplete inscription by *Tiberinius Celerianus* (RIB 3014), which dates from the AD 160s, identifies him as being a Roman citizen from northern France and as a *moritix*, a Celtic word for seafarer (Dondin-Payre and Loriot, 2008). There also exists a writing tablet concerning the sale of a Gaulish slave girl called *Fortunata* – ‘Lucky’ (Tomlin, 1993). Other examples include the *procurator* Julius Classicianus who is suggested to have been from *Gallia Belgica* near Trier (Germany); and Lucius Pompeius Licetus Da(…) from *Arretium* (Italy) (RIB 3004) (Pearce, 2010). It is clear from the above that the populace of *Londinium* represented communities from a variety of different geographic areas of the Empire.

Isotope analysis-based mobility data for individuals from *Londinium* is currently sparse, particularly lead and strontium isotope data, although three small-scale studies have identified migrants from North Africa, Europe and other locales in Britain (Budd, no date; Millard et al., 2013; Montgomery 2002; Montgomery et al., 2010). This study represents the first large-scale application of lead isotope analysis to address the geographical origin of individuals in Roman Britain.

2.1 Using lead and strontium to track mobility in Roman Britain

The use of isotopes in archaeological studies is based on the premise that humans tend to incorporate isotopic compositions that correspond to those of locally sourced resources (Schwarcz et al., 2010:337). Strontium and oxygen isotopes have long been used to identify non-locals based on geological and climatic differences during childhood (Evans et al., 2006a, 2006b; Budd et al., 2001). However, due to the rise in the anthropogenic use of lead during the Roman period, lead (Pb) isotope analyses, coupled with strontium (Sr) isotope analyses, provide a unique opportunity for tracing migration during this period (Montgomery, 2002). The rise in anthropogenic Pb exposure in Roman Britain is acknowledged as a significant post-conquest change (Boulakia, 1972; Montgomery et al., 2010). In the Roman world, the industrial uses of the metal were multiple, including in plumbing, cooking, dyeing, cosmetics, tableware, and coffins (Boulakia, 1972; Durali-Müller, 2005). Its widespread use in the province can be explained by the natural occurrence of the ore in the north and southwest of England and Wales (Boulakia, 1972).

The increased use of Pb in Roman Britain provides a unique investigative tool with which to identify people from this period. In pre-metallurgical societies the Pb in the skeleton will reflect the geology from which the Pb originated and is present only in small concentrations (<0.8 ppm) (Millard et al., 2014; Montgomery, 2002; Montgomery et al., 2010). In contrast, in metallurgical societies, such as Roman Britain, the naturally occurring Pb in the body can become 'swamped' by anthropogenic sources of Pb ore, resulting in higher concentrations (Budd et al., 2004) and a narrower range of isotope ratios, first described by Montgomery et al. (2005) as 'cultural focusing'. This refers to the increase in a population's Pb burden and the convergence of isotope ratios toward an average value of anthropogenic Pb sources used by the population (Montgomery et al., 2010:212). The idea behind this concept is that the use of Pb and access to Pb ore sources will differ between cultural groups, which will consequently affect the level and isotopic composition of Pb exposure for a given group.

Sr isotope studies have also been used to identify migrants in Roman Britain (Chenery et al., 2010, 2011; Eckardt et al., 2009, 2014; Evans et al., 2010; Montgomery et al., 2011). However, as these and other studies have shown, because similar geological terrains are found in both Britain and northern Europe, British biosphere Sr isotope ratios are not sufficiently unique to differentiate between individuals local to Britain and those from the Continent (Evans et al., 2012). However, a comparison of Sr and Pb isotope ratios may aid in the interpretation of the data.

2.2 Characterizing the Sr and Pb isotope signature of individuals raised in London and assessing reference datasets for potential non-London origins.

The Sr isotope composition ($^{87}Sr/^{86}Sr$) of the area currently occupied by London is predominantly within the biosphere isotope range of 0.709-0.710 (Evans, et al., 2010). This area of London is bound on both sides by chalk, which has a range of Sr isotope composition between 0.708 – 0.709. Hence, individuals whose childhood was spent in the London area would be expected to have a tooth enamel Sr isotope composition that falls within the range of 0.708 to 0.710. A study of Post-Medieval individuals excavated from Chelsea Old Church (Trickett et al., 2003) provides a direct measurement for individuals from London as 0.70936±0.0009 (2SD, n=23, one sample omitted). Sr concentrations in British tooth enamel have a median value of 83 ppm and mean of 103± 68 ppm (1SD) (calculated from data in Evans, et al., 2012) with higher concentrations predominantly associated with marine Sr isotope compositions of 0.70920 (Evans et al., 2012).

There are a number of types of Pb isotope composition ($^{207}Pb/^{206}Pb$ and $^{208}Pb/^{206}Pb$) reference datasets against which the data from samples in this study can be compared. The most profuse are published Pb isotope analysis of lead ore (galena) available in the geological literature (e.g. Haggerty et al., 1996; Stos-Gale et al., 1995, 1996, 1998). These isotope ratios only provide a compositional range of the analysed ore minerals and do not directly reflect the expected ranges for human dental enamel. Additionally, much of these data are low precision measurements undertaken using thermal ionisation mass spectrometry (TIMS). Some data, such as that from the Mendips (Haggerty et al., 1996), has been measured using the more modern, higher precision plasma ionisation methodology. However, as noted, these ore field data sets give a broad range of geological values for a region. Alternatively, the measurement of Pb isotopes in well provenanced metal artefacts can provide a more realistic range of isotope composition that reflects the range of isotope compositions due to anthropogenic reworking of the ores. Pb ranges from human tooth enamel, for populations of geographically constrained origin, provide the best comparative data sets.

In this study we use the ore field data from the Mendips (Haggerty et al., 1996) to provide the field of English/Welsh ore Pb isotope compositions, and the human enamel Pb isotope composition of a group of individuals from the Post-Medieval period of London (18th-19th century) to provide the British anthropogenic Pb isotope field (Millard et al., 2014); this essentially coincides with the field described in Montgomery et al. (2010). As we are interested not only in local individuals but those of possible non- *Londinium/Britannia* origin, we also analysed datasets that represent non-English/Welsh Pb ore sources, in particular those regions that belonged to the Roman Empire, including the circum-Mediterranean and northern Europe.

The circum-Mediterranean is defined by high precision Pb isotope data on Roman coins (Butcher and Ponting, 2014), minted predominantly in Italy, Greece, Turkey and Egypt. Three samples of human tooth enamel from Rome plot within this field validating it as a reasonable proxy for human enamel from these regions (see Montgomery et al., 2010). The

Rhine area of Germany (*Germania*) is given by Pb isotope data from Roman artefacts found in this area (Bode et al., 2009).

The Pb reference datasets (Fig. 1) show the clear isotope difference between the fields of British, Germany, and circum-Mediterranean derived Pb. There is some overlap between the fields and it should be noted that these reference datasets do not provide a unique solution as other regions of the continent/world could supply similar values, therefore we can only interpret the results within the constraints of available data.

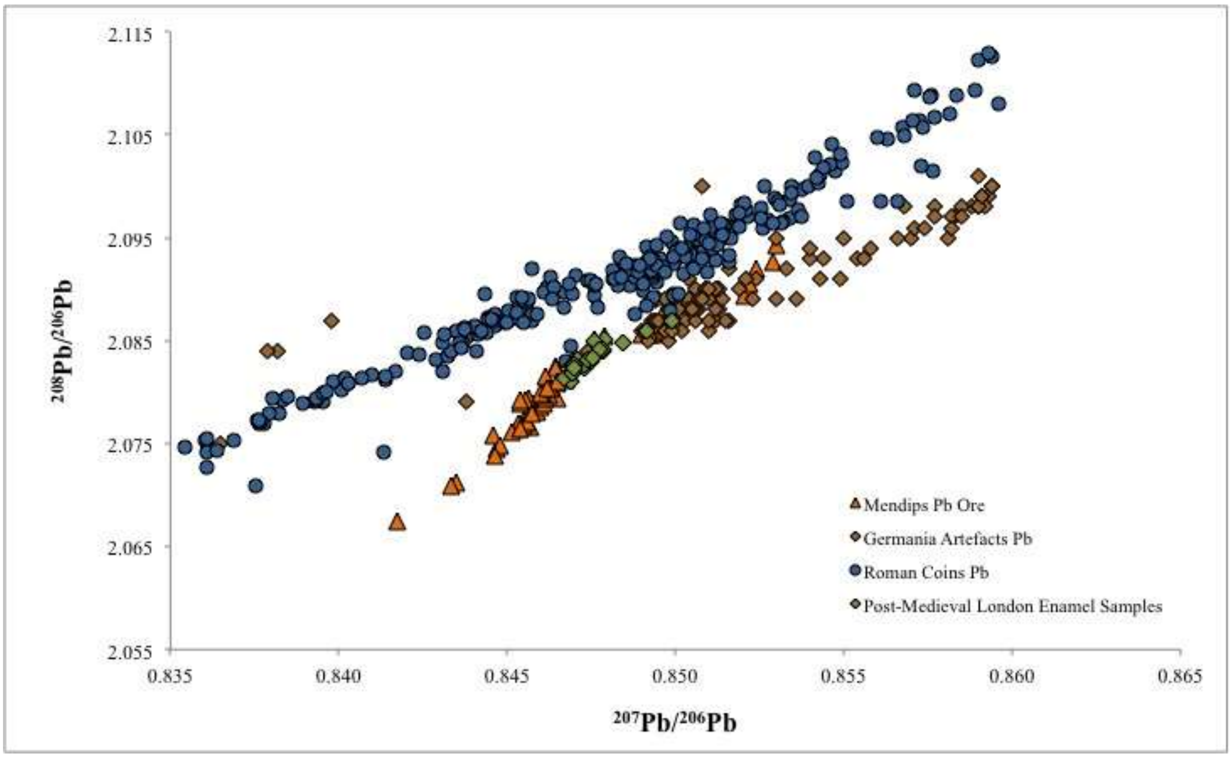

Fig 1. Comparative datasets showing the trends in Pb isotope ratios for both Pb objects and enamel samples for different geographic regions. Data for Mendips Pb Ore from Haggerty et al. (1996), data for Roman coins from Butcher and Ponting (2014), and data for Post-Medieval London dental enamel samples from Millard et al. (2014).

3.0 Materials and methods

3.1 The human remains

Twenty individuals were selected for this study. Table 1 provides information about the sex, age-at-death, burial location, burial context and grave goods, and date of these burials; Figure 2 provides a map showing the location of the sites from which each burial was excavated. Note that in the Roman period, formal burial grounds were located outside of *Londinium* in accordance with Roman law (Toynbee, 1971). The individuals were recorded following the protocols and methods produced by the Museum of London (Powers, 2007, 2012). Age-at-death was determined in subadults (≤ 18 years old) using dental eruption and development, long-bone length, and epiphyseal fusion (Scheuer and Black, 2000). In adults (≥ 18 years old), dental wear (Brothwell, 1981), degenerative changes at the sternal rib end (İsçan and

Loth, 1986a, 1986b), auricular surface and pubic symphyseal face (Brooks and Suchey, 1990; Lovejoy et al., 1985) were employed. Sex determination was limited to those ≥ 18 years old, and was based on morphological differences in the skull and pelvis (Phenice, 1969; Buikstra and Ubelaker, 1994). As per the aims of this study, sample selection focused on including individuals who reflect different variables of *Londinium*'s population. As such, it included individuals of both sexes and all ages, individuals from different phases of the settlement, and individuals with varied funerary treatment.

Table 1. The Londinium samples, their accompanying contextual information, and estimated migrant status

Site Name and Code	Context Number	Date (AD)	Sex	Age (Years old)	Burial context (post-excavation burial numbers given in parentheses)	Reference
201 Bishopsgate (BGB98)	400	170-400	Subadult	8	(B400) Wooden coffin with chalk/chalk-like substance; 3 copper alloy bracelets placed by the right ankle; 6 very small fragments of a fine wire chain	Swift (2003)
St Bartholomew's Hospital (BAR79)	325	200-300	Female	18-25	(B12) Wooden coffin; 7 bronze bracelets and 2 bronze finger-ring placed in a pile on the torso; a miniature bronze bell and a fragment of copper bracelet was recovered from the overlying fill	Bentley and Pritchard (1982)
Cotts House (COT88)	30	43-400	Male	18-25	Iron object recovered from fill but probably originally located on the left torso.	Schofield with Maloney (1998)
Great Dover Street (GDV96)	325	125-175	Female	18-25	(B22) Deep blue glass counter from grave fill; 2 very small fragments of fire-damaged glass probably from a disturbed cremation; scatter of 8 hobnails, placed over left side of pelvis. Pre-term infant (28 weeks old) (B23) found by right foot	Mackinder (2000)
	150	101-300	Subadult	7	(B26) Wooden coffin with chalk/chalk-like substance; pyriform glass vessel; incomplete jet pin; unworn hobnail shoes and chicken skeleton at the foot of grave	Mackinder (2000)
Hooper Street (HOO88)	518	120-300	Female	36-45	(B623) Wooden coffin; no grave goods	Barber and Bowsher (2000)
	652	117-400	Male	>18	(B636) Wooden coffin; no grave goods	Barber and Bowsher (2000)
	1407	100-200	Female	>18	(B656) Wooden coffin; no grave goods	Barber and Bowsher (2000)

	1673	250-400	Female	>18	(B709) Wooden coffin; inside coffin and unworn by right arm: 2 jet pendants, jet necklace; worn on left wrist: copper alloy bracelet; lead allow bowl inside coffin by left foot; disc mouthed flagon (unworn) inside coffin by right arm; Thameside Kent ware jar inside coffin and unworn by foot	Barber and Bowsher (2000)
60 London Wall (LOW88)	695.5	125-200	Male	36-45	No grave-goods; interred in a pit with other disarticulated human remains	Redfern and Bonney (2014)
	803.6	40-100	Male	26-35	No grave-goods; interred in a ditch with other disarticulated human remains	Redfern and Bonney (2014)
65-73 Mansell Street (MNL88)	37	180-400	Male	>46	(B604) No coffin or grave goods	Barber and Bowsher (2000)
49-55 Mansell Street (MSL87)	163	300-400	Female	>18	(B291) Wooden coffin; a pottery flagon was placed by the head; a wooden casket was placed at her feet. It contained: a silver bracelet, a copper-alloy bracelet, an iron bracelet with some textile fragments, a jet bracelet, a carved chalcedony intaglio, a carved carnelian intaglio, a deep blue glass carved intaglio, an emerald bead, 2 green glass beads, 2 bone dies, a sheet of silver foil folded into a fan-shape and 11 coins. Also present were a lead-alloy plate, a jet bead and possible hobnails.	Barber and Bowsher (2000)
	390	350-410	Female	36-45	(B374) Wooden coffin. Inside the coffin: an unworn Alice Holt/Farnham flagon placed at the left foot; a pair of worn *tutuli* brooches on either side of the torso; a worn decorated triangular composite antler comb placed at head	Barber and Bowsher (2000)

	724	350-410	Male	>46	(B538) Wooden coffin. Inside the coffin: an unworn green glass bottle above head; an unworn green glass bottle next to head; worn gilded copper-alloy crossbow brooch by right upper arm; unworn copper-alloy chip-carved belt set placed on left arm	Barber and Bowsher (2000)
Spitalfields Market (SRP98)	23873	250-400	Subadult	5	(B118) No coffin. A Moselkeramik beaker with a white painted votive message (no trans). Other possible high status grave goods may be associated with this burial (e.g. a glass vessel)	Thomas (in prep)
	34209	250-400	Male	26-35	(B168). No coffin or grave goods	Thomas (in prep)
	34245	270-350	Male	>46	(B167). Wooden coffin with chalk/chalk-like substance. Five vessels recovered from grave fill: 4 beakers (2 unsourced fabric, 2 Nene Valley, 1 with painted decoration) and a miniature black-burnished Alice Holt/Farnham bowl	Thomas (in prep)
24-30 West Smithfield (WES89)	599	43-410	Female	36-45	No coffin but buried on a bed of chalk/chalk-like substance	Schofield and Maloney (1998)
	709	43-410	Female	36-45	No coffin or grave goods	Schofield and Maloney (1998)

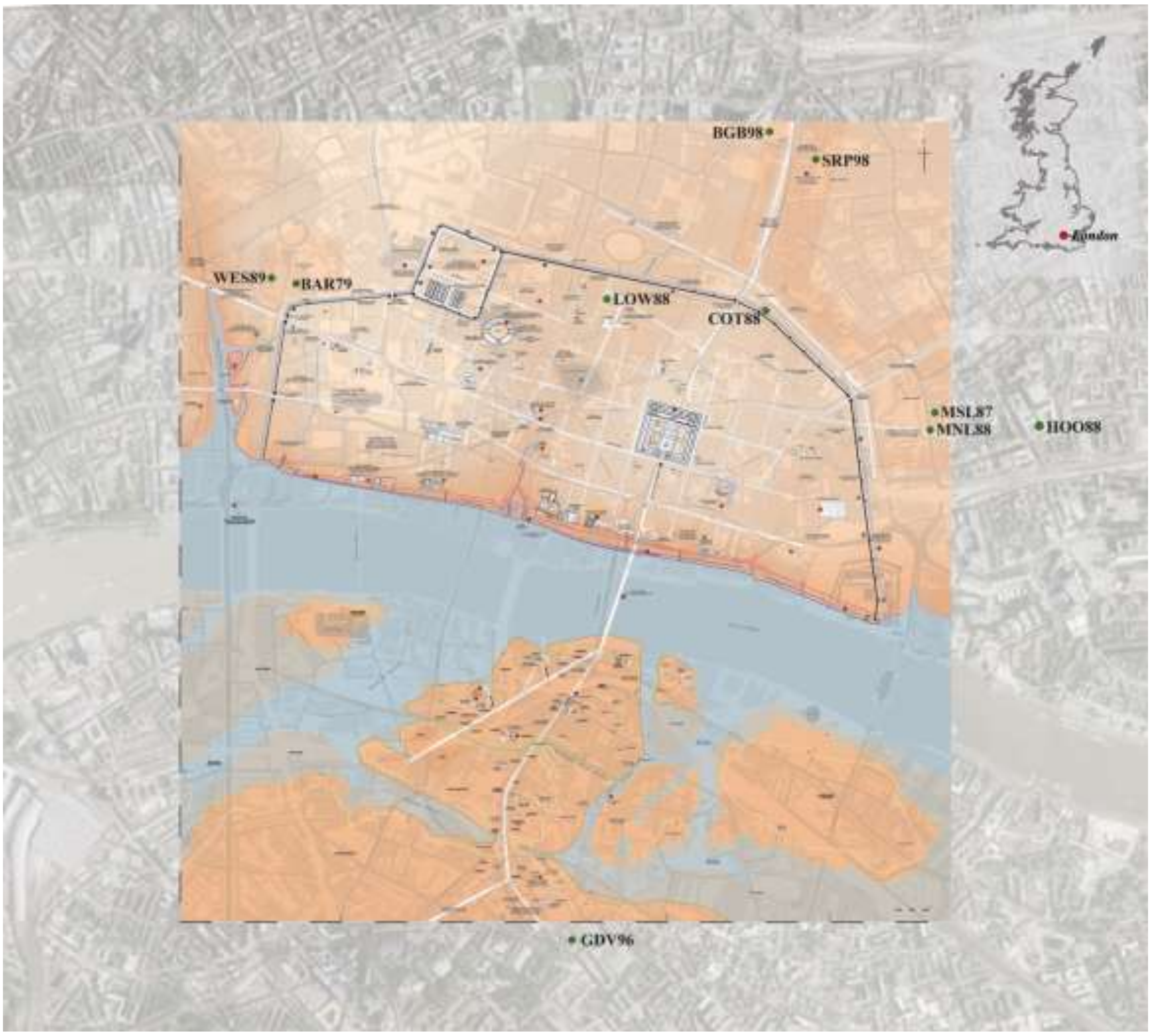

Fig 2. Map of Roman London overlaying a map of modern London showing the limits of the settlement and the location and site codes where sampled individuals were recovered (Base map © Museum of London, Museum of London Archaeology, and Google Earth; site codes mapped by Authors).

3.2 The dental sample

The preferred material for analysis of Pb and Sr isotopes in archaeological skeletal material is enamel. Tooth enamel is optimal for these analyses, as once formed, the enamel is not remodelled, and therefore represents snap shots of the averaged Sr and Pb isotopes incorporated during the mineralization process in childhood (Budd et al., 2000). Importantly, core enamel has shown to be resistant to diagenetic alteration for both Pb and Sr isotopes, whereas bone and dentine have not (Chiaradia et al., 2003; Hoppe, 2004; Montgomery, 2002; Trickett et al., 2003). Furthermore, because teeth form at known ages, it is possible to select teeth in order to examine a particular stage of childhood (Montgomery, 2010). Dental enamel samples were taken from the canine (6 months to 5 years old), first (1.5-6 years old) and second premolars (3-7 years old), first (birth to 3 years old) and second (3 to 7 years old) molars (Smith, 1991). Ante-mortem tooth loss and dental wear prevented the selection of the same tooth across the sample (Table 2).

Table 2. Dental sample information: selected tooth (T) is given using the Federation Dentaire International code (FDI)

Site Name and Code	Context	Tooth (FDI)	Sample Weight
Spitalfields Market (SRP98)	34245	T13	57.4 mg
Hooper Street (HOO88)	518	T17	36 mg
Cotts House (COT88)	30	T37	27.3 mg
49-55 Mansell Street (MSL87)	390	T35	31.4 mg
60 London Wall (LOW88)	803.6	T25	69.1 mg
24-30 West Smithfield (WES89)	709	T27	46.8 mg
Great Dover Street (GDV96)	325	T35	55.8 mg
Hooper Street (HOO88)	1673	T27	72.2 mg
Hooper Street (HOO88)	652	T25	61.8 mg
65-73 Mansell Street (MNL88)	37	T25	43.8 mg
Hooper Street (HOO88)	1407	T37	52.3 mg
Spitalfields Market (SRP98)	34209	T37	57.4 mg
60 London Wall (LOW88)	695.5	T13	39.4 mg
24-30 West Smithfield (WES89)	599	T45	35.9 mg
49-55 Mansell Street (MSL87)	163	T27	22.0 mg
49-55 Mansell Street (MSL87)	724	T45	40.4 mg
201 Bishopsgate (BGB98)	400	T26	52.8 mg
Great Dover Street (GDV96)	150	T16	32.9 mg
Spitalfields Market (SRP98)	23873	T46	52.2 mg
St Bartholomew's Hospital (BAR79)	182	T27	52.5 mg

3.3 Sample preparation

The methods employed have been tested in multiple studies and have shown to successfully prevent contamination and remove potentially diagenetic material (Budd et al., 2000; Evans et al., 2006a, 2006b; Montgomery, 2002). Each tooth crown was abraded from the surface to a depth of approximately 100µm using a tungsten carbide dental bur and prepared using the methodology described by Montgomery (2002). Discoloured, carious, cracked or damaged areas of the enamel were avoided. A slice of dental enamel was removed from the tooth wall longitudinally from the cusp to the cemento-enamel junction and to the depth of the enamel-dentine junction using a flexible diamond-edged rotary dental saw; masses ranged from 22-73 mg (Table 2). All dentine tools were ultrasconicated in Decon® and rinsed thrice between samples to avoid cross contamination. All samples were free of adhering dentine.

3.4 Isotope measurement

The resulting core enamel samples were chemically processed and subsequently analyzed in a clean class 100, HEPA©-filtered laboratory at the NERC Isotope Geosciences Laboratory (NIGL). All twenty samples were placed in individual beakers with MilliQ© water, covered with parafilm©, and cleaned in an ultrasonic bath for five minutes each. The samples were then rinsed and placed on a hot plate (60°C) for approximately one hour. The samples were rinsed several times in MilliQ© water and allowed to dry. A known amount of ^{84}Sr tracer solution was added to the weighted sample, which was then dissolved Teflon distilled 8M of Nitric Acid (HNO_3) and allowed to dry down overnight.

The enamel residue with taken up in 1 ml of 1% HNO_3 and 0.5% hydrochloric acid (HCL). An aliquot of the liquid sample was then set aside into labeled sterile tubes to be analysed for Pb concentration levels. The remaining sample was converted to bromide form and the Pb separated out using of anion exchange resin (AG 1X8). The non Pb bearing fraction from the anion resin separation was converted to chloride form and Sr separated out using Dowex AG 50X8 resin

The Pb isotope composition was measured using a Nu Industries Nu Plasma MC-ICP-MS (multicollector inductively coupled plasma mass spectrometer) and introduced to the instrument via an ESI 50ul/min PFA micro-concentric nebulizer attached to a desolvating unit (Nu DSN 100). The precision and accuracy of the machine was assessed through repeat analysis of a 5ppb NBS981 Pb standard solution spiked with thallium. The values were then compared to the known values for this standard (Thirlwall, 2002). The reproducibility of the NBS981 for each isotope is as follows: $^{206}Pb/^{204}Pb$ ± 0.010; $^{207}Pb/^{204}Pb$ ±0.017; $^{208}Pb/^{204}Pb$±0.020; $^{207}Pb/^{206}Pb$ ± 0.010; $^{208}Pb/^{206}Pb$±0.012.

Sr isotope ratios and concentrations were determined by Thermal Ionisation Mass Spectrometry (TIMS) using a Thermo Triton multi-collector mass spectrometer. The prepared samples were loaded onto a single Re filament following the method of Birck (1986). The international standard for $^{87}Sr/^{86}Sr$, NBS987, gave a value of 0.71025±0.00001 (n=8, 2s) during the analysis of these samples. Blanks were in the region of 100pg.

4.0 Results

4.1 Lead isotopes

Pb concentrations range between 0.24 and 14.7 ppm (Table 3). With the exception of LOW88-803.6, who had the lowest concentration of 0.24 ppm, the Pb concentrations for all of the samples were ≧ 1ppm. These elevated Pb levels are consistent with exposure and uptake of anthropogenic Pb.

Table 3. Lead and strontium isotope results

Site	Context	Pb Concentration (ppm)	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{206}Pb$	$^{208}Pb/^{206}Pb$	Sr Concentration (ppm)	$^{87}Sr/^{86}Sr$
Spitalfields Market (SRP98)	34245	7.38	18.5700	15.6590	38.6940	0.84323	2.0838	268	0.70896
Hooper Street (HOO88)	518	4.04	18.4860	15.6460	38.5240	0.84637	2.0840	127	0.70889
Cotts House (COT88)	30	2.70	18.4460	15.6370	38.4170	0.84773	2.0827	46	0.70828
49-55 Mansell Street (MSL87)	390	9.35	18.4460	15.6390	38.4440	0.84782	2.0841	50	0.71221
60 London Wall (LOW88)	803.6	0.24	18.4430	15.6530	38.5330	0.84867	2.0894	96	0.71033
24-30 West Smithfield (WES89)	709	2.50	18.4590	15.6360	38.4720	0.84708	2.0843	94	0.70968
Great Dover Street (GDV96)	325	10.56	18.4607	15.6620	38.6170	0.84809	2.0912	161	0.70928
Hooper Street (HOO88)	1673	3.03	18.4370	15.6380	38.4420	0.84817	2.0850	130	0.70976
Hooper Street (HOO88)	652	2.09	18.4030	15.6320	38.4240	0.84943	2.0880	70	0.70951
65-73 Mansell Street (MNL88)	37	3.05	18.4317	15.6353	38.4139	0.84830	2.0842	90	0.70933
Hooper Street (HOO88)	1407	4.61	18.4420	15.6360	38.4530	0.84779	2.0850	135	0.70940
Spitalfields Market (SRP98)	34209	1.31	18.4350	15.6370	38.4350	0.84814	2.0849	88	0.70895
60 London Wall (LOW88)	695.5	1.00	18.4050	15.6340	38.4310	0.84947	2.0882	137	0.70900
24-30 West Smithfield (WES89)	599	2.17	18.4550	15.6370	38.4730	0.84727	2.0847	112	0.70973
49-55 Mansell Street (MSL87)	163	2.37	18.4190	15.6330	38.4020	0.84874	2.0850	95	0.70947
49-55 Mansell Street (MSL87)	724	1.57	18.4700	15.6340	38.4420	0.84642	2.0812	130	0.70914

201 Bishopsgate (BGB98)	400	4.41	18.3360	15.6360	38.3580	0.85275	2.0920	120	0.71236
Great Dover Street (GDV96)	150	14.65	18.4700	15.6460	38.5170	0.84707	2.0854	153	0.70924
Spitalfields Market (SRP98)	23873	2.83	18.4600	15.6430	38.4790	0.84738	2.0844	101	0.70951
St Bartholomew’s Hospital (BAR79)	182	1.33	18.4660	15.6380	38.4360	0.84685	2.0815	57	0.70909

The Pb isotope data from the samples is plotted relative to the reference fields described earlier (Fig. 3). The majority of the data plot within or close to the field of English Pb ore sourced from the Mendips and the cultural focusing range identified by Montgomery et al. (2010). These individuals show no evidence of non-local origin.

Seven samples have a Pb isotope composition that is not consistent with an English/London anthropogenic signature: LOW88-695.5, LOW88-803.6, SRP98-34245, HOO88-652, GDV96-325, GDV96-150, and BGB98-400.

SRP98-34245 and GDV96-325 have isotope compositions that plot within the field of the Romans coins (Ponting and Bucher, in press); BGB98-400 plots within the *Germania* field at the upper end of the English Pb ore field array (Bode et al., 2009); and HOO88-652 and LOW88-695.5 have Pb isotope compositions that are within the Pb range identified for the Mendip Pb ore field data (Haggerty et al., 1996), but not within the central anthropogenic field defined by the Post-Medieval London data (Millard et al. 2014). LOW88-803.6 plots between these latter two samples and GDV96-325. GDV96-150's Pb isotope composition plots on the edge of the anthropogenic Pb isotope composition range defined by the Post-Medieval London data, but well within the Pb range identified by the Mendip Pb ore field data.

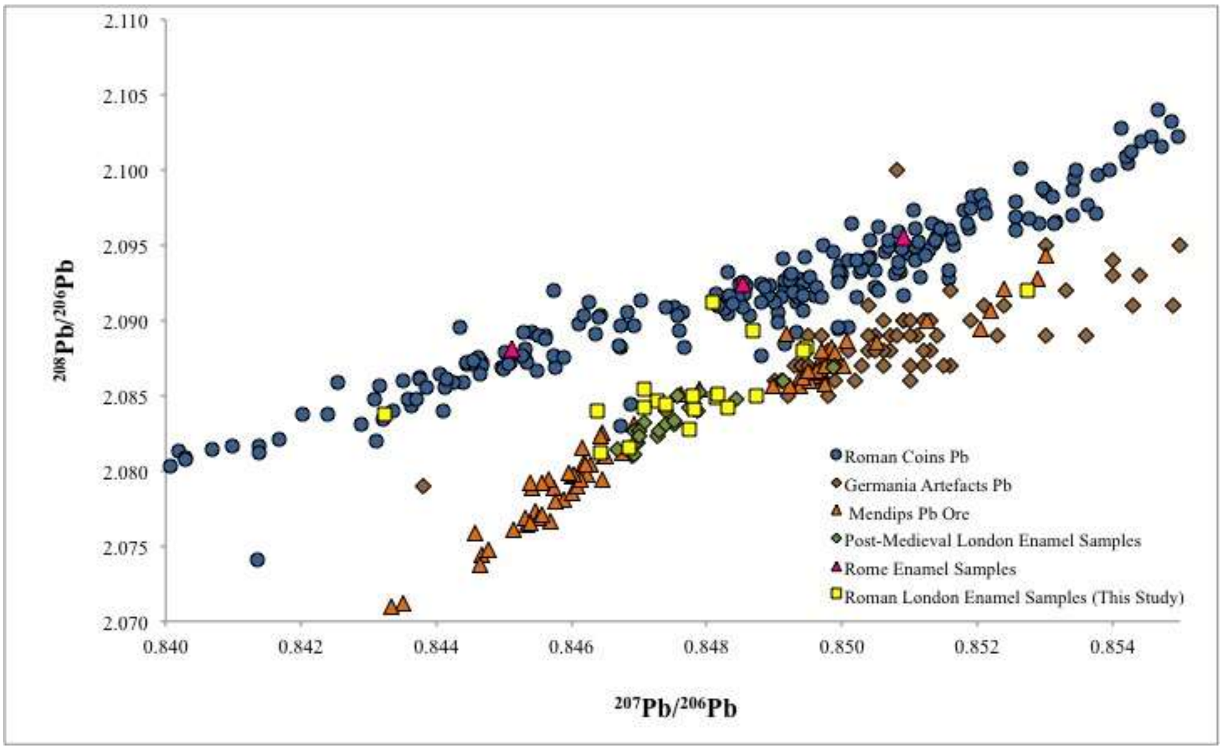

Fig. 3 Bivariate plot showing the Pb isotope results for this study in relation to comparative datasets for different geographic regions. Data for German artefacts come from Bode et al. (2009), data for Roman coins come from Butcher and Ponting (2014), Mendips Pb Ore come from Haggerty et al. (1996), data for Post-Medieval London dental enamel samples come from Millard et al. (2014), and data for the Rome dental enamel samples come from Montgomery et al. (2010).

4.2 Strontium isotopes

The results of both the Sr concentrations and the isotope ratios are presented in Table 3. The total isotopic range for this sample population is 0.70828-0.71236. The mean for the 20 samples is 0.7096±0.0010 (1 SD), with the majority of the individuals falling within the range of 0.7090-0.7100. Sr concentrations range from 46-268 ppm, with a mean value of 113± 49 ppm (1SD, n=19). The majority of results fall between 50-161ppm, with only one individual (SRP98-34245) having a higher concentration at 268 ppm (Fig. 4). The data are plotted relative to the theoretical range of Sr isotope compositions in the London area, and against the means and 1SD of British tooth enamel concentration, calculated from data in Evans et al. (2012). On the basis of this diagram, the majority of the individuals have Sr isotope compositions consistent with a childhood origin within the modern London environs and Sr concentrations that are consistent with English origins. Three individuals (LOW88-803.6, MSL87-390, BGB98-400) have isotopes ratios well outside of the London range; the first three have ratios above the London range, whereas COT88-30 has a low ratio of 0.7082, which could be derived from the chalk underlying areas south of the River Thames (Evans, et al., 2010). Only one individual (SRP98-34245) has a Sr concentration (268ppm) beyond the 2SD range of English data.

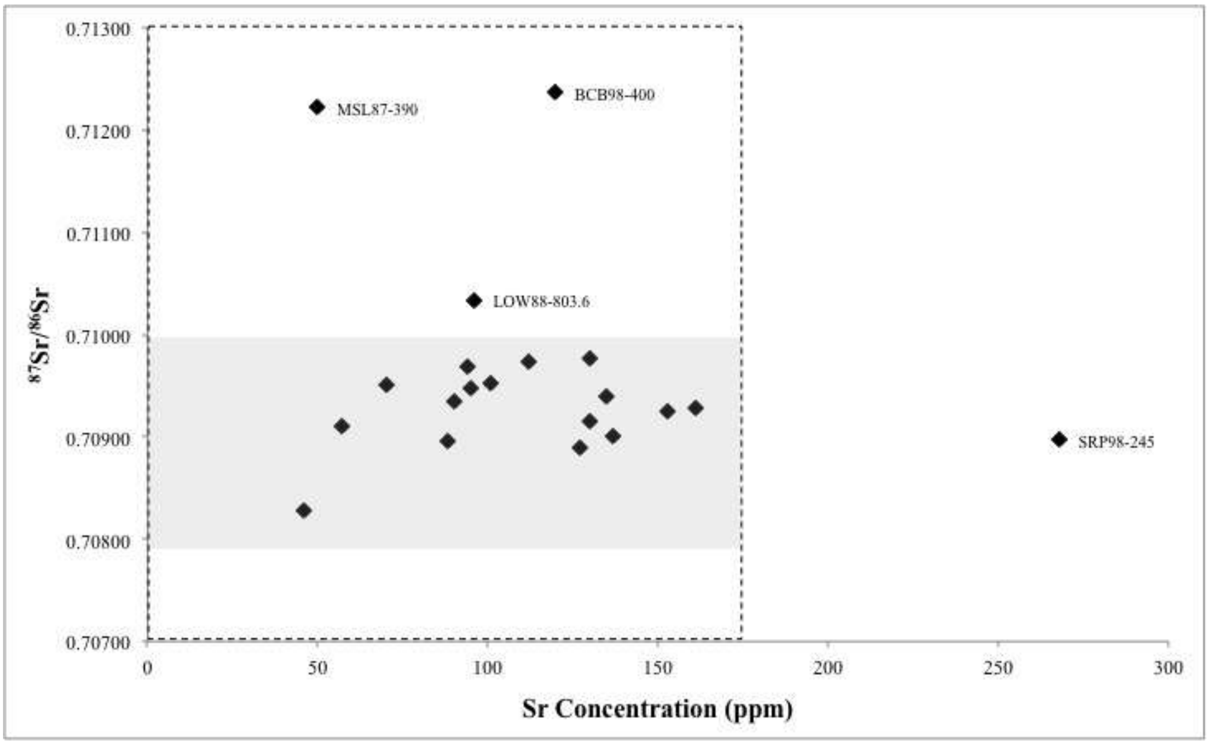

Fig 4. Bivariate plot of $^{87}Sr/^{86}Sr$ and Sr concentrations. The area delineated by the dashed line represents data results expected for England; the shaded area represents the Sr isotope ratio expected for individuals from the London area (Evans et al., 2012). 2SD errors are found within the symbols.

5.0 Discussion

5.1 Individuals 'local' to *Londinium*

Twelve individuals in this study had Sr and Pb isotope ratios consistent with a *Londinium*/Roman British origin. The majority of the burials from this 'local' group vary considerably in terms of the presence/absence of coffins and grave goods (Tables 1 and 4), reflecting the broad variation in Roman London funerary practices. These people included the high status 18-25 year old female (BAR79-182) who was buried with jewellery and a miniature bronze bell; her burial is unparalleled in Roman London (Table 1). In a Roman life course perspective, younger adult females in this 18-25 year age category were more likely to be buried with jewellery than older females and this may relate to marital status (Evans Grubb, 2002; Gowland, 2001; Harlow and Laurence, 2002; Martin-Kilcher, 2000; Pearce, 2011; Rawson, 1991).

There were also a number of individuals who had a burial context and grave goods suggestive of a non-local origin, but were shown through isotopic analysis to most likely originate from *Londinium*. This includes MSL87-724, an older (>46 years) male, buried in a wooden coffin and accompanied by a crossbow brooch and an unworn belt buckle (Barber and Bowsher, 2000). The brooch and belt are very distinctive items: crossbow brooches were used to fasten heavy outer garments at the shoulder, and are considered to have formed part of the uniform of a 4th century soldier or state official who had achieved a certain rank. The distribution of these brooch types is biased towards military zones but they have also been found in the burials of women and children (Collins, 2010). They are believed to indicate a high social status and may suggest that the wearer spent a period of time in Imperial service, such as a military officer (Collins, 2010, 2013). The belt buckle was synonymous with the Roman military community, with primary sources remarking that it enabled them to be identified as a distinctive social group when not dressed in full-armour (Hoss, 2011a, 2011b). Like the brooch, the chip-carved style is considered to have military connections, and the wearing of belts by veterans may reflect an honourable discharge (Hoss, 2011b). Given his local isotope profile, the unworn belt may suggest cultural or ancestral connections to the Continent and the military, rather than as a place of origin (Barber and Bowsher, 2000; Cool, 2010b; Pearce, 2010; see also, Eckardt et al., 2014, in press).

5.2. Individuals non-local to *Londinium*

Four of the individuals display a variety of isotope characteristic that suggest they did not spend their childhood in *Londinium* (Tables 1 and 4) and these are discussed below.

5.2.1 A 36-45 year old female (MSL87-390),

MSL87-390 is a 36-45 year old female with an elevated ^{87}Sr/^{86}Sr ratio of 0.71222 and an anthropogenic English Pb isotope composition. The ^{87}Sr/^{86}Sr ratio is consistent with areas such as southwest England, Wales, Scotland, and elsewhere in the Continent but not *Londinium* or even most of Roman Britain (Evans et al., 2010). She was buried with rare large disc-like brooches (*tutulus)* and a composite triangular antler comb (Barber and

Bowsher, 2000). The jewellery type has strong connections with Germany, and has been suggested by some to reflect ethnic affiliations (see Swift 2010).

This is a unique burial in *Londinium* and the style of dress signifies a non-local identity that is in keeping with her Sr isotope profile. Her Pb isotope composition, however, is within the range of a Roman British origin and may either be suggesting that this individual originated from somewhere within Roman Britain other than *Londinium* (based on her Sr isotope composition), but has a strong cultural affiliation with Germany; or that this individual originated from a region of the Roman Empire (possible Germany) with an anthropogenic Pb composition similar to Roman Britain. As for the latter possibility, there is currently very little comparative anthropogenic Pb isotope data for elsewhere in the Roman Empire and Northern Europe that it is difficult to say how likely this possibility is. This is further compounded by the fact that had she come from a region outside of Roman Britain that used primarily southern British sourced ore, her Pb composition would be indistinguishable from indigenous Roman British individuals.

5.2.2 Eight year old from Bishopsgate (BGB98-400)

The subadult, BGB98-400, has an elevated Sr isotope composition of 0.71237 and a Pb isotope composition that is outside the English anthropogenic Pb field (Montgomery et al., 2010; Millard et al., 2014); the Pb isotope composition sits towards the upper end of the English ore field and close to the centre of the data from *Germania*. A concentration of 4.4 ppm suggests the Pb exposure was not simply a natural, geogenic exposure and the subadult may have originated in an area near the Rhine Valley of Germany where both the Sr (Voerkelius, et al., 2010) and Pb (Bode et al., 2009) isotope compositions could be accommodated. The isotopic composition for BGB98-400 did not conform to the local status initially determined for this individual based on the burial context and grave goods, which included being laid on a bed of chalk-like material in a wooden coffin, with three bronze bracelets and a piece of wire chain placed next to the right ankle (see Swift, 2003) (Table 1). The use of wooden coffins and the inclusion of bronze bracelets are often found in subadult and young adult female burials in *Londinium* and elsewhere in Roman Britain (e.g. Colchester) (Barber and Bowsher, 2000; Gowland, 2001; Hamlin, 2007; Pearce, 2011; Swift, 2003). The grave-goods, therefore, did not strongly suggest a foreign origin when compared to other isotopically identified migrant burials in Roman London (Swain and Roberts, 1999; Montgomery et al., 2010).

5.2.3 18-25 year old female (GDV96-325)

GDV96-325 is a 18-25 year old female interred with a blue glass counter, a hobnail shoe placed on the left side of her pelvis, and a pre-term infant (28 weeks old) by her right foot (Table 1). She has a high tooth enamel Pb concentration (10 ppm) and plots within the field of circum-Mediterranean anthropogenic Pb isotope composition (Fig. 3). This would strongly suggest her childhood was spent outside of *Britannia* and the high exposure to Pb may suggest that this individual was of a higher social status. In contrast, both her Sr isotope composition and Sr concentration value are compatible with a childhood spent in the London area. As noted previously, though, the Sr isotope ratios of the London area are shared with other parts of Europe; the Sr isotope results, therefore, are not necessarily indicative of a local origin. No aDNA has been undertaken to establish whether these individuals represent a mother and her infant. The presence of an infant may indicate a fatal premature delivery (Kelmar et al., 1995). Nevertheless, it was commonplace in *Britannia* for infants to be buried with adults (Gowland et al., 2014)

5.2.4 Older adult male (SRP98-34245)

This individual (SRP98-34245) has Pb isotope ratios consistent with the area around Rome (Italy). He has a very high Sr concentration (beyond the 2SD range for British tooth enamel) of 268ppm and a Sr isotope composition that would be consistent with limestone regions around the Mediterranean (Henderson et al., 2009; Pellegrini et al., 2008; Brems et al., 2013; Rich et al., 2012). In addition to being characteristic of coastal maritime islands, higher enamel concentrations also appear to occur in more arid climates (Buzon et al., 2007) and so a high concentration may indicate origins in a hot, more southerly climate. Given the use of chalk/chalk-like substance in the grave (McKenzie and Thomas, in prep), the high Sr concentration and the low $^{87}Sr/^{86}Sr$ value, the possibility of post-mortem contamination with chalk was considered for this sample. However, the lead is not indicative of chalk (see Montgomery et al. 2010) and even if the sample, despite rigorous preparation protocols, was subject to significant Sr contamination, this individual would still be classed as of non-British origin on the lead isotopes alone. It is entirely conceivable that the high Sr concentration, whilst unusual in a British context, is genuine and consistent with non-British origins.

5.3 Individuals with inconclusive isotope results

Four individuals had inconclusive results. The adult male HOO88-652 has Pb isotope results that are suggestive of a non-local origin, but not conclusively. Without additional evidence, it is not possible to make a confident determination of this individual's migrant status based on the isotope results alone.

GDV96-150 is the high status burial of a seven-year-old child, who was buried with a glass flask, jet pin, hobnails, and accompanying chicken burial (Table 1). This individual's Sr composition is consistent with a childhood spent in *Londinium*, but had the highest Pb concentration at 14.6 ppm of the entire sample set and a Pb isotope ratio that falls on the edge of the English ore Pb field, possibly suggesting a non-local origin. However, the proximity of this individual to the anthropogenic English Pb ore field is close enough to be suggestive of a local origin. While likely local, without more data it is difficult to conclusively determine this individual's origins.

LOW88-803.6 is a cranium recovered from a pit outside the city walls and has a Pb isotope composition that plots in an area where the Roman coin data field and the Pb isotope composition of the Mendip Ore field overlap, but are outside the field of anthropogenic English Pb. He displays the lowest Pb ppm concentration of all twenty samples at 0.24ppm which strongly suggests no, or minimal, exposure to anthropogenic sources of Pb during childhood (Montgomery et al., 2010). He also has a slightly elevated Sr isotope composition

(0.71034), which would support a non-*Londinium* origin, although, cannot independently rule out a childhood spent elsewhere in *Britannia*. However, there is currently very little published comparative data for Pb isotopes in people which derive solely from natural sources, in an analogous way to Sr, prior to the Roman period and none which match this individual (Montgomery et al., 2010).

The cranium LOW88-695.5 was recovered from as the same site as LOW88-803.6 and has a Pb isotope composition that is on the edge of the anthropogenic English Pb ore field. Additionally, this individual has one of the lowest Pb concentrations at 1 ppm. Although this individual could be non-local, as with GDV96-150 above, he falls too close to the culturally defined group to definitively exclude him being from Roman Britain. Moreover, the Sr isotope composition for this individual, however, is compatible with a *Londinium* origin. However, as mentioned previously, the Sr isotope ratios for the London area are shared with many other parts of Europe.

Both LOW88-695.5 and LOW88-803.6 were recovered from a series of pits and ditches in an industrial area inside of the city walls and both are suggested to be examples of disarticulated remains of people who had died in the arena or been head-hunted by the Roman military. The possible migrant status of these individuals adds some interesting possibilities to these proposed scenarios (Redfern and Bonney, 2014).

5.4 Significance of findings

Traditionally, the cultural affinity of an individual is interpreted through the study of the person's grave goods, burial practices, and other material evidence. Recent studies correlating isotope evidence with grave-good provisioning, however, have overwhelmingly found that the cultural construction of identity is not always a true reflection of where a person spent their childhood. Instead these data provide us with a more nuanced perspective on how funerary identities were created and displayed in Roman Britain (Cool, 2010a; Eckardt, 2010; Eckardt et al., 2009, 2014; Pearce, 2010).

This study builds upon this work by demonstrating a heterogeneous pattern with regard to funerary context and childhood residence. For example, two of the *Londinium* sample set were late Roman individuals from Mansell Street (MSL87) who were interred with items traditionally associated with non-local origins (Pearce, 2010, 2011, 2013). The male burial from Mansell Street (MSL87-764) with a 'Germanic-style' crossbow brooch and belt-set was likely to be local to *Londinium*. By contrast, a later, adult female burial from the same site, was interred with 'Germanic' dress items (MSL87-390), is non-local. The adoption of 'Germanic' personal ornamentation was a cultural choice, whereby people were affiliating themselves with this community through their familial connections, or because of other social relationships, such as the military (Cool, 2010a, 2010b; Eckardt, 2014; Eckardt et al., 2014, in press).

This study has also added to the growing body of evidence for the mobility of women and children in the Roman Empire. The child, BGB98-400, whose isotope evidence potentially indicated an origin in the Rhine valley (Germany) (Swift 2003), although there may be other places where comparable ratios may be found, is now one of two subadults who show evidence for childhood migration to *Londinium* (Millard et al., 2013). There is also increasing evidence for child migrants elsewhere in Roman Britain, most notably at Vindolanda (Northumberland) (Vindolanda Charitable Trust, 2010; BBC News, 2012).

This study has also indicated two individuals who may have originated from the circum-Mediterranean, including the female GDV96-325. This woman exhibited isotope values comparable to the female burial from Spitalfields Market, known as 'Spitalfields Woman', who was previously analysed by Montgomery et al. (2010) and is identified as being from Rome. Another burial with Pb isotopes similar to those found in the Mediterranean was that of an adult male, SRP98-34245. His Pb isotope ratios are comparable to those from the Roman coin array. Interestingly, this 'non-local' male burial was unusual in that the grave was chalk-lined and contained five pottery vessels (McKenzie and Thomas, in prep) (Table 1). Archaeological and primary source evidence from the Mediterranean indicates that the use of chalk and/or embalming was a high-status funerary rite, which appears to have originated in North Africa (Brettell, 2013, 2014; Pearce, 2013). However, despite their non-local origin, it is suggested that in this case, the use of chalk is more likely to reflect funerary expenditure rather cultural or ancestral affiliation.

The use of Pb isotope analysis significantly aided the interpretation of the geographic origins of this sample of burials from Roman London. Pb isotope analysis was able to highlight unusual isotopic values in instances where the Sr isotopes were inconclusive. Pb isotopes were also valuable in terms of refining potential areas of childhood residency. The isotopic evidence also corroborates information found in the epigraphic record for *Londinium*, indicating the presence of people from Northern Europe and the Mediterranean.

5.0 Conclusions

In our sample of 20 individuals from *Londinum*, we suggest that four people had migrated from outside of the settlement and that twelve people were either born in and/or grew up in the immediate Roman London area. The origins of the remaining four individuals are less clear. Our results lend further weight to the results of other isotopic studies addressing origin, cultural identity, and funerary practice in Roman Britain, where there is not always a direct correlation between these variables (Cool, 2010a; Eckardt, 2010, 2014; Eckardt et al., 2014; Pearce, 2010). The data for people coming from Germany, Italy and elsewhere on the Continent does correlate to the inscription evidence from the settlement, and reflects what we know about the presence of the military and Imperial administration in the settlement. The presence of migrant inhabitants throughout its history ensured that the settlement was a diverse and unique settlement from its foundation until its eventual abandonment in the 5th century AD. Finally, this study highlights the utility of Pb isotope analysis in the study of population mobility in the Roman Empire.

6.0 Acknowledgements and thanks

RR is most grateful to Jelena Bekvalac, Roy Stephenson and Caroline McDonald with for all their help and support with this project. RR also thanks Rhea Brettell, Heather Bonney and

Lynne Bell for allowing us to use their unpublished results, and the advice of Rob Collins and Stephanie Hoss regarding the two ‘German’ burials. The authors are grateful to the NERC Isotope Geosciences Laboratory for the use of their facilities.

7.0 Bibliography

Adams, C., Laurence, R. (Eds.), 2001. Travel and geography in the Roman Empire. Taylor and Francis, London.

Barber, B., Bowsher, D., 2000. The eastern cemetery of Roman London. Excavations 1983-1990. Museum of London Archaeology Monograph 4, London.

BBC News, 2012. Child skeleton at Vindolanda fort 'from Mediterranean'. BBC News Tyne & Wear. http://www.bbc.co.uk/news/uk-england-tyne-19399441 (Accessed 14/7/14).

Bentley, D., Pritchard, F.A., 1982. The Roman Cemetery at St. Bartholomew's Hospital. Transactions of the London and Middlesex Archaeological Society 33, 134-172.

Birck, J.L., 1986. Precision K, Rb Sr isotopic analysis: application to Rb Sr chronology. Chem Geol 56, 73-83.

Bode, M., Hauptmann, A., Mezger, K., 2009. Tracing Roman lead sources using lead isotope analyses in conjunction with archaeological and epigraphic evidence- a case study from Augustan/Tiberian Germania. Archaeological and Anthopological Sciences 1, 177-194.

Boulakia, J.D.C., 1972. Lead in the Roman world. Am J Arch 36, 36-64.

Brems, D., Ganio, M., Latruwe, K., Balcaen, L., Carremans, M., Gimeno, D., Silvestri, A., Vanhaecke, F., Muchez, P., Degryse, P., 2013. Isotopes on the beach, part I: Strontium isotope ratios as a provenance indicator for lime raw material used in Roman glass-making, Archaeometry 55, 214-234.

Brettell, R., 2013. Report on the evidence for resins in Roman London 1. University of Bradford.

Brettell, R., 2014. Report on the evidence for resins in Roman London 2. University of Bradford.

Brigham, T., 1996. The port of Roman London, in Watson, B., (Ed.), Roman London: recent archaeological work. Including papers given at a seminar held at The Museum of London on 16 November 1996. J Rom Arch Suppl 24, 23-34.

Brooks, S., Suchey, J.M., 1990. Skeletal age determination based on the os pubis: a comparison of the Acsádi-Nemeskéri and Suchey-Brooks methods, Hum Evol 5, 227-238.

Brothwell, D.R., 1981. Digging up bones. The excavation, treatment and study of human skeletal remains, 3rd ed., Cornell University Press, USA.

Budd, P., no date. Combined O-, Sr- and Pb-isotope analysis of dental tissues from a Neolithic individual from Shepperton and an Iron Age individual from Southwark, London. Archaeotrace Report No.106.

Budd, P., Montgomery, J., Barreiro, B., Thomas, R.G., 2000. Differential diagenesis of strontium in archaeological human dental tissues. Appl Geochem 15, 687-694.

Budd, P., Montgomery, J., Evans, J., Chenery, C., Holland, G. & Tanner, S., 2001. Combined Pb-, Sr- and O-isotope analysis of human dental tissue for the reconstruction of archaeological residential mobility. Plasma Source Mass Spectrometry 267, 311-323.

Budd, P., Montgomery, J., Evans, J., Trickett, M., 2004. Human lead exposure in England from approximately 5500 BP to the 16th century AD. Sci Total Environ 318, 45-58.

Buikstra, J.E., Ubelaker, D.H., 1994. Standards for data collection from human skeletal remains. Proceedings of a seminar at the Field Museum of Natural History organized by Jonathan Haas, Arkansas Archaeological Survey Research Series No 44, Arkanas.

Butcher, K., Ponting, M., 2014. The Metallurgy of Roman Silver Coinage From the Reform of Nero to the Reform of Trajan, Cambridge University Press.

Buzon, M.R., Simonetti, A. & Creaser, R.A. (2007) Migration in the Nile Valley during the New Kingdom period: a preliminary strontium isotope study. J Archaeol Sci 34, 1391-1401.

Chenery, C., Müldner, G., Eckardt, H., Lewis, M., 2010. Strontium and stable isotope evidence for diet and mobility in Roman Gloucester, UK. J Archaeol Sci 37, 150-163.

Chenery, C., Eckardt, H., Müldner, G., 2011. Cosmopolitian Catterick? Isotopic evidence for population mobility on Rome's northern frontier. J Archaeol Sci 38, 1395-1770.

Chiaradia, M., Gallay, A., Todt, W., 2003. Different contamination styles of prehistoric human teeth at a Swiss necropolis (Sion, Valais) inferred from lead and strontium isotopes. Appl Geochem 18, 353-370.

Collingwood, R. G. & Wright, R. P. The Roman Inscriptions of Britain (reprinted with corrections, 1995), (Gloucester: Alan Sutton 1995) (RIB I).

Collins, R., 2010. Brooch use in the 4th-to 5th-century frontier, in: Collins, R., Allason-Jones, L. (Eds.), Finds from the Frontier: material culture in the 4th-5th centuries. CBA, York, 64-77.

Collins, R., 2013. Soldiers to warriors: renegotiating the Roman frontier in the fifth century, in: Hunter, F., Painter, K. (Eds.), Late Roman Silver: the Traprain Treasure in context. Society of Antiquaries of Scotland, Edinburgh, 29-43.

Cool, H.E.M., 2010a. Finding the foreigners, in: Eckardt, H. (Ed.), Roman diasporas: archaeological approaches to mobility and diversity in the Roman Empire. J Rom Arch Suppl 78, 27-44.

Cool, H.E.M., 2010b. A different life, in: Collins, R., Allason-Jones, L. (Eds.), Finds from the Frontier. CBA Research Report, York, 1-9.

Dondin-Payre, M., Loriot, X., 2008. Tiberinius Celerianus à Londres : Bellovaque et moritix. L'Antiquité Classique 77, 127-169.

Durali-Müller, S., 2005. Roman lead and copper mining in Germany: their origin and development through time, deduced from lead and copper isotope provenance studies, PhD thesis, Frankfurt am Main.

Eckardt, H., (Ed.), 2010. Roman diasporas: archaeological approaches to mobility and diversity in the Roman Empire. J Rom Arch Suppl 78.

Eckardt, H., 2014. Objects and identities: Roman Britain and the north-western provinces. Oxford University Press, Oxford.

Eckardt, H., Booth, P., Chenery, C., Müldner, G., Evans, J.A., Lamb, A., 2009. Isotopic evidence for mobility at the late Roman cemetery at Lankhills, Winchester. J Archaeol Sci 36, 2816-2825.

Eckardt, H., Chenery, C., Leach, S., Lewis, M., Müldner, G., Nimmo, E., 2010. A long way from home: diaspora communities in Roman Britain, in: Eckardt, H. (Ed.). J Rom Arch Suppl 78, 99-130.

Eckardt, H., Müldner, G., Lewis, M., 2014. People on the move in Roman Britain. Wld Archaeol 46, 534-550.

Eckardt, H., Müldner, G., Speed, G., In Press. The late Roman field army in Northern Britain? Mobility, material culture and multi-isotope analysis at Scorton (N. Yorks). Britannia, 46.

Evans, J., Stoodley, N., Chenery, C., 2006a. A strontium and oxygen isotope assessment of a possible fourth century immigrant population in a Hampshire cemetery, southern England. J Archaeol Sci 33, 365-372.

Evans, J.A., Chenery, C.A., Fitzpatrick, A.P., 2006b. Bronze Age childhood migration of individuals near Stonehenge, revealed by strontium and oxygen isotope tooth enamel analysis. Archaeometry 48, 309-321.

Evans, J., Montgomery, J., Wildman, G., Boulton, N., 2010. Spatial variations in biosphere 87Sr/86Sr in Britain. J Geol Soc London 167, 1-4.

Evans, J., Chenery, C., Montgomery, J., 2012. A summary of strontium and oxygen isotope variation in archaeological human tooth enamel excavated from Britain. J Anal At Spectrom 27, 754-764.

Evans Grubb, J., 2002. Women and the law in the Roman Empire: a sourcebook on marriage, divorce and widowhood. Routledge, London.

George, M. (Ed.), 2013. Roman slavery and Roman material culture. University of Toronto Press, Toronto.

Gowland, R., 2001. Playing dead: implications of mortuary evidence for the social construction of childhood in Roman Britain, in: Davies, G., Gardner, A., Lockyear, K. (Eds.), TRAC 2000. Proceedings of the Tenth Annual Theoretical Roman Archaeology Conference, London 2000. Oxbow Books, Oxford, 152-168.

Gowland, R., Chamberlain, A.T., Redfern, R., 2014. On the brink of being: re-evaluating infanticide and infant burial in Roman Britain, in: Carroll, M., Graham, E.-J. (Eds.), Infant health and death in Roman Italy and beyond. J Rom Arch Suppl 96, 69-88.

Haggerty, R., Budd, P., Rohl, B., Gale, N.H. 1996. Pb-isotope evidence for the role of Mesozoic basins in the genesis of Mississippi Valley-type mineralization in Somerset, UK. J Geol Soc 153, 673-676.

Hall, J., 1996. The cemeteries of Roman London, in: Bird, J., Hassall, M., Sheldon, H. (Eds.), Interpreting Roman London. Papers in memory of Hugh Chapman. Oxbow Monograph 58, Oxford, 57-84.

Hamlin, C., 2007. Material expression of social change: the mortuary correlates of gender and age in late Pre-Roman Iron Age and Roman Dorset. PhD Thesis, University of Wisconsin-Milwaukee, Milwaukee.

Harlow, M., Laurence, R., 2002. Growing up and growing old in ancient Rome: a life course approach. Routledge, London.

Henderson, J., Evans, J., Barkoudah, Y., 2009. The roots of provenance: glass, plants and isotopes in the Islamic Middle East, Antiquity 83, 414-429.

Hill, J., Rowsome, P., 2011. Roman London and the Walbrook stream crossing: excavations at 1 Poultry and vicinity, City of London. Museum of London, London.

Holder, N., 2007. Mapping the Roman Inscriptions of London. Britannia 38, 13-34.

Hoppe, K.A., 2004. Late Pleistocene mammoth herd structure, migration patterns, and Clovis hunting strategies inferred from isotopic analyses of multiple death assemblages. Paleobiology 30, 1, 129-145.

Hoss, S., 2011a. A theoretical approach to Roman military belts, in: Sanader, M., Rendić-Miočević, A., Tončinić, D., Radman-Livaja, I. (Eds.), Proceedings of the XVIIth Roman Military Equipment Conference: weapons and military equipment in a funerary context. XVII Roman Military Equipment Conference, Zagreb, 24th-27th May, 2010, 317-326.

Hoss, S., 2011b. The Roman military belt, in: Koefoed, H., Nosch, M.-L. (Eds.), Wearing the cloak. Dressing the soldier in Roman times. Ancient Textile Series, Oxford, 29-44.

İşçan, M., Loth, S., 1986a. Determination of age from the sternal rib in white males: a test of the phase method, J Foren Sci 31, 122-132.

İşçan, M., Loth, S., 1986b. Determination of age from the sternal rib in white females: a test of the phase method, J Foren Sci 31, 990-999.

Kelmar, C.J.H., Harvey, D., Simpson, C., 1995. The sick newborn baby, 3rd ed. Bailliere Tindall, London.

Leach, S., Lewis, M.E., Chenery, C., Müldner, G.H., Eckardt, H., 2009. Migration and diversity in Roman Britain: a multidisciplinary approach to immigrants in Roman York, England. Am J Phys Anthropol, 140, 546-556.

Lovejoy, C.O., Meindl, R.S., Pryzbeck, T.R., Mensforth, R.P., 1985. Chronological metamorphosis of the auricular surface of the ilium: a new method for the determination of age at death, Am J Phys Anthropol 68, 15-28.

Mackinder, Anthony. 2000. A Romano-British cemetery on Watling Street: excavations at 165 Great Dover Street, Southwark, London. MoLAS Archaeology Studies Series 4. Museum of London Archaeology Service, London

McKenzie, M. Thomas, C., (Eds.), in prep. The Roman cemetery at St Mary Spital, London, Museum of London Archaeology Monograph, London.

Marsden, P., 1986. Roman London, 3rd ed. Thames and Hudson, London.

Martin-Kilcher, S., 2000. 'Mors immatura' in the Roman world: a mirror of society and tradition, in: Pearce, J. (Ed.), Burial, society and context in the Roman World. Oxbow Book, Oxford, 78-84.

Mattingly, D., 2006. An imperial possession: Britain in the Roman Empire. Penguin Books Ltd, London.

Mattingly, D., 2011. Urbanism, epigraphy and identity in the towns of Britain under Roman rule, in: Schellenberg, H.M., Hirschmann, V.E., Krieckhaus, A. (Eds.), A Roman miscellany: essays in honour of Anthony R. Birley on his seventieth birthday. Akanthina Monograph Series 3, Gdansk, Poland, 53-71.

Millard, A.R., Johnson L. Gröcke, D. 2013. Isotopic investigation of diet and mobility, in Ridgeway, V., Leary K., Sudds, B. (Ed.), Roman burials from Southwark. Excavations at 52-65 Lant Street and 56 Southwark Bridge Road, London SE1. London, PCA Monograph 17, 65-70.

Millard, A., Montgomery, J., Trickett, M., Beaumont, J., Evans, J., Chenery, S., 2014. Childhood Lead Exposure in the British Isles during the Industrial Revolution, Modern Environments and Human Health. John Wiley & Sons, Inc, New York, 279-299.

Millett, M., 1996a. Characterizing Roman London, in: Bird, J., Hassall, M., Sheldon, H. (Eds.), Interpreting Roman London. Papers in memory of Hugh Chapman. Oxbow Books, Oxford, 33-38.

Millett, M., 1996b. Introduction: London as capital? J Rom Arch Suppl 24, 7-12.

Molleson, T., Elrdige, D., Gale, N., 1986. Identification of lead sources by stable isotope ratios in bones and lead from Poundbury Camp, Dorset. Oxf J Arch 9, 249-253.

Montgomery, J., 2002. Lead and Strontium Isotope Compositions of Human Dental Tissues as an Indicator of Ancient Exposure and Population Dynamics. Dept. of Archaeological Sciences, University of Bradford, Bradford.

Montgomery, J., 2010. Passports from the past: investigating human dispersals using strontium isotope analysis of tooth enamel. Ann Hum Biol 37, 325-346.

Montgomery, J., Evans, J.A., Powlesland, D., Roberts, C.A., 2005. Continuity or colonization in Anglo-Saxon England? Isotope evidence for mobility, subsistence practice, and status at West Heslerton. Am J Phys Anthropol 126, 123-138.

Montgomery, J., Evans, J.A., Chenery, S.R., Pashley, V., Killgrove, K., 2010. 'Gleaming, white and deadly': the use of lead to track human exposure and geographic origins in the Roman period in Britain, in Eckardt, H., (Ed.), 2010. Roman diasporas: archaeological approaches to mobility and diversity in the Roman Empire. J Rom Arch Suppl 78, 199-126.

Montgomery, J., Knüsel, C.J., Tucker, K., 2011. Identifying the origins of decapitated male skeletons from 3 Driffield Terrace, York, through isotope analysis. Reflections of the cosmopolitan nature of Roman York in the time of Caracalla, in: Bonogofsky, M. (Ed.), The bioarchaeology of the human head: decapitation, decoration, and deformation. University of Florida Press, Florida, 141-178.

Müldner, G.H., Chenery, C., Eckardt, H., 2011. The 'Headless Romans': multi-isotope investigations of an unusual burial ground from Roman Britain. J Archaeol Sci 38, 280-290.

Müldner, G., 2013. Stable isotopes and diet: their contribution to Romano-British research. Antiquity 87, 137-149.

Pearce, J., 2010. Burial, identity and migrations in the Roman world, in: Eckardt, H. (Ed.), Roman diasporas: archaeological approaches to mobility and diversity in the Roman Empire. J Rom Arch Suppl 78, 79-98.

Pearce, J., 2011. Representations and realities: cemeteries as evidence for women in Roman Britain. Medicina nei Secoli 23, 227-254.

Pearce, J., 2013. Beyond the grave. Excavating the dead in the late Roman provinces. Late Antique Arch 9, 441-482.

Pellegrini, M., Donahue, R.E., Chenery, C., Evans, J., Lee-Thorp, J., Montgomery, J., Mussi, M., 2008. Faunal migration in late-glacial central Italy: implications for human resource exploitation, Rapid Commun. Mass Spectrom. 22, 1714-1726.

Perring, D., 1991. Roman London. Seaby, London.

Perring, D. 2015. 'Recent advances in the understanding of Roman London', in Fulford, M. and Holbrook, N. eds. The Towns of Roman Britain. The contribution of commercial archaeology since 1990, London: Roman Society, 20-43.

Perring, D. and Pitts, M. 2013. Alien cities. Consumption and the origins of urbanism in Roman Britain, Spoilheap Monograph 7, London.

Phenice, T.W., 1969. A newly developed visual method of sexing the os pubis. Am j Phys Anthropol 30, 297-301.

Pollard, A.M., Ditchfield, P., McCollagh, J.S.O., Allen, T.G., Gibson, M., Boston, C., Clough, S., Marquez-Grant, N., Nicholson, R.A., 2011. ‘‘These Boots Were Made For Walking’’: The Isotopic Analysis of a C4 Roman Inhumation From Gravesend, Kent, UK. Am J Phys Anthropol 146, 446-456.

Powers, N. 2007. A rapid method for recording human skeletal data. Second Edition. Museum of London.

Powers, N., 2012. Human osteology method statement. Museum of London, London. http://archive.museumoflondon.org.uk/NR/rdonlyres/3A7B0C25-FD36-4D43-863E-B2FDC5A86FB7/0/OsteologyMethodStatementrevised2012.pdf (Accessed 16/7/14).

Rawson, B., 1991. Adult-child relationships in Roman society, in: Rawson, B. (Ed.), Marriage, divorce, and children in Ancient Rome. Clarendon Press, Oxford, 7-30.

Redfern, R., Bonney, H., 2014. Headhunting and amphitheatre combat in Roman London, England: new evidence from the Walbrook Valley. J Archaeol Sci 43, 214-226.

Rich, S., Manning, S.W., Degryse, P., Vanhaecked, F., Lerberghe, K.V., 2012. Strontium isotopic and tree-ring signatures of Cedrus brevifolia in Cyprus. J Anal At Spectrom 27, 796-806.

Rowsome, P., 1996. The development of the town plan of early Roman London, in Watson, B., (Ed.), Roman London: recent archaeological work. Including papers given at a seminar held at The Museum of London on 16 November 1996. J Rom Arch Suppl 24, 35-46.

Scheuer, L., Black, S., 2000. Developmental juvenile osteology, Academic Press, London.

Schofield, J., Maloney, C., (Eds.), 1998. Archaeology in the City of London, 1907-1991: a guide to records of excavations by the Museum of London and its predecessors. The Archaeological Gazetteer Series, Volume 1. Museum of London, London.

Schwarcz H., White, C.; Longstaffe, F., 2010. Stable and radiogenic isotopes in biological archaeology: Some applications. In J. West, Bowen, G.; Dawson, T.; Tu, K. (ed.) Isoscapes: Understanding movement, pattern, and process on Earth through isotope mapping. London: Springer, 335-356.

Sheppard, F.,1998. London: A History. Oxford: Oxford University Press.

Sidell, J., 2008. Londinium's landscape, in: Clark, J., Cotton, J., Hall, J., Sherris, R., Swain, H. (Eds.), Londinium and beyond. Essays on Roman London and its hinterland for Harvey Sheldon. CBA, York, 62-68.

Smith, B.H., 1991. Standards of human tooth formation and dental age assessment, in: Kelly, M.A., Larsen, C.S. (Eds.), Advances in dental anthropology. Wiley-Liss, New York, 143-168.

Stos-Gale Z., Gale, N.; Houghton, J.; Speakman, R., 1995. Lead isotope data from the Isotrace Laboratory, Oxford: Archaeometry database 1, ores from the Western Mediterranean. Archaeometry 37, 407-415.

Stos-Gale Z., Gale, N.; Annetts, N., 1996. Lead isotope data from the Isotrace Laboratory, Oxford: Archaeometry database 3, ores from the Agean, part 1. Archaeometry 38, 381-390.

Stos-Gale Z., Gale, N.; Annetts, N.; Todorov, T.; Lilov, P.; Raduncheva, A.; Panayotov, I., 1998. Lead isotope data from the Isotrace Laboratory, Oxford: Archaeometry database 5, ores from Bulgaria. Archaeometry 40, 217-226.

Swain, H., Roberts, M., 1999. The Spitalfields Roman. Museum of London, London.

Swan, V., 1993. Legio VI and its men: African legionaries in Britain. J Rom Pottery Stud 5, 1-34.

Swift, D., 2003. Roman burials, medieval tenements and suburban growth: 201 Bishopsgate, City of London. MoLAS Archaeology Studies Series 10, London.

Swift, E. 2010. Identifying migrant communities: a contextual analysis of grave assemblages from Continental Late Roman Cemeteries. *Britannia* 41: 237-282.

Thirlwall, M., 2002. Multicollector ICP-MS analysis of Pb isotopes, using a (207) Pb-(204) Pb double spike, demonstrates up to 400ppm/amu systematic errors in T1 normalization. Chem Geol 184, 255-279.

Tomlin, R.S.O., 1993. 'The girl in question': a new text from Roman London. Britannia 34, 41-51.

Tomlin, R. S. O. 2006. 'Was Roman London ever a Colonia?', in R. Wilson ed. Romanitas : essays on Roman archaeology in honour of Sheppard Frere on the occasion of his ninetieth birthday, Oxford: Oxbow, 58-64.

Tomlin, R. S. O., Wright, R.P., Hassall, M.W.C., 2010. Roman Inscriptions of Britain, Volume III, Oxford: Oxbow [RIB III].

Toynbee, J.M.C., 1971. Death and burial in the Roman world. Thames & Hudson, London.

Trickett, M.A., Budd, P., Montgomery, J., Evans, J., 2003. An assessment of solubility profiling as a decontamination procedure for the sup87/sup Sr/sup 86/sup Sr analysis of archaeological human skeletal tissue. Appl Geochem 18, 653-658.

Vindolanda Charitable Trust, 2010. Excavation news 2010. www.vindolanda.com/LiteratureRetrieve.aspx?ID=41685 (Accessed 14/7/14).

Voerkelius S, Lorenz GD, Rummel S, Quetel CR, Heiss G, Baxter M, Brach-Papa C, Deters-Itzelsberger P, Hoelzl S, Hoogewerff J, Ponzevera E, Van Bocxstaele M, Ueckermann H. 2010. Strontium isotopic signatures of natural mineral waters, the reference to a simple geological map and its potential for authentication of food. Food Chem. 118, 933-40.

Wallace, L. 2014. The Origin of Roman London. Cambridge: Cambridge University Press.

Wheeler, R.E.M., 1928. An inventory of the Historical Monuments in London. Volume 3: Roman London. Royal Commission on the Ancient and Historical Monuments and Constructions of England, London.